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Description of a New Measuring Rod. By Edward Crossley.

Some ten years ago I had occasion to triangulate across a valley 3,000 feet wide on the south side of my observatory at Bermerside, Halifax. In order to accomplish this with sufficient accuracy it was necessary to measure a base line to 1 in 10,000. I soon discovered that no *simple* and *accurate* method had yet been devised for this purpose. The ordinary surveyor's chain or steel tape was quite inadequate for the purpose, especially as the ground was more or less uneven. The elaborate methods used in geodetic surveys were also out of the question on account of their great complexity. I therefore determined to construct a measuring rod on simple geometric principles, capable of doing accurate and rapid work over uneven ground, with or without the aid of an assistant.

The first rod I designed for this purpose was made for me by Messrs. T. Cooke and Sons of York. It was made of well-seasoned red deal, 1 inch thick, 6 feet in length, with a **T** section $2\frac{1}{2}$ inches wide and 4 inches deep in the centre. At each end, on the under flat surfaces, brass plates were attached with spherical cups in their centres, facing downwards. In the middle of the rod was placed a clinometer reading to 30″ of arc. Three stout, firm tripods were used for carrying the rod. Each tripod terminated in a flat iron ring, faced in the lathe, $6\frac{1}{2}$ inches in outside diameter and 4 inches internal diameter. On these rings were placed brass pedestals with circular bases 6 inches diameter, surmounted by spheres or balls $\frac{7}{8}$ inch diameter, the top of the balls not being more than $2\frac{1}{2}$ inches above the surface of the rings. Each pedestal had a spindle going through the ring, with a brass tribrach "washer" and clamp, milled head screw nut on the under side of the iron ring, so that the pedestal could be clamped anywhere within the area of the ring. The spherical heads were turned of equal size, to fit the cups on the measuring rod. In the first instance stout posts with brass-headed nails in their centres were used for terminals.

The method of procedure was as follows. A tripod was set up over the first post and the spherical head clamped, with the plumb bob over the brass nail. A correction was applied for any inclination of the ring. A piece of string 60 feet in length with tabs every 6 feet was stretched on the ground in the direction of the base line, to facilitate the setting of the tripods. B tripod was set over the first tab and C tripod over the second, with the heads unclamped. The measuring rod was now placed upon the heads of A and B tripods. The head of B tripod being unclamped was free to take the position necessary to fit the cup at the end of the rod.

After lining, B head was clamped and the clinometer read off. Then the same process was repeated on B and C tripods.

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A tripod was set forward over the tab in advance of C, and so on to the end of the base.

The following results were thus obtained in 1883 from three measurements of the same base line :—

	Feet.	Differences.		
			μ	in.
I.	442·635	15	34	$\frac{1}{5}$
II.	442·612	8	18	$\frac{1}{10}$
III.	442·612	8	18	$\frac{1}{10}$
	442·620	10	23	$\frac{1}{8}$

N.B.—μ = millionths of the whole distance.

These results were so encouraging that I determined to go a step further, and secure results of an accuracy of not less than 1 in 100,000.

For this purpose I made another rod, 10 feet in length, of well-seasoned pine, with a T section, but with an opening $\frac{1}{2}$ inch square from end to end, through which a steel rod $\frac{1}{4}$ inch diameter passed. The steel rod was firmly attached at each end to brass plates with spherical cups, and two thermometers were also attached to the rod. Fresh terminals were used, consisting of iron castings, with $\frac{1}{2}$-inch vertical holes in their centres, buried in the ground, the surface of the ground being made good by iron box frames and lids.

Adopting precisely the same method as before, the following results were obtained in 1886 :—

	Feet.	Differences.			Feet.	Differences.		
			μ	in.			μ	in.
I.	836·33022	461	5·5	$\frac{1}{18}$	442·89724	72	1·6	$\frac{1}{111}$
II.	836·33786	303	3·6	$\frac{1}{28}$	442·89682	114	2·3	$\frac{1}{71}$
III.	836·33640	157	1·9	$\frac{1}{52}$	442·89981	185	4·2	$\frac{1}{45}$
	836·33483	307	3·7	$\frac{1}{27}$	442·89796	124	2·8	$\frac{1}{66}$

Thus a greater accuracy than 1 in 100,000 was obtained.

The 10-feet measuring rod was afterwards further improved by making the wood portion of square box section, and supporting the steel rod on rollers along the centre of the box. Simple means were also adopted for measuring intermediate lengths with an accuracy of 1-100th of an inch. The thermometers were bedded to the steel rod with mercury amalgam. A detached thermometer was also placed inside the box near to one of the other thermometers, and the steel rod was blackened throughout its whole length to increase its thermal conductivity, the weight of the whole rod being about 12 lbs.

In order to determine the exact value of the measuring rod I have designed a variable end standard, which Messrs. Troughton and Simms have constructed for me.

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It consists of a cold-drawn steel tube $1\frac{1}{4}$ inch external diameter, with a telescopic or sliding piece at one end having a range of 1 inch. The ends are parallel plane surfaces. By means of a vernier, scale, and reading microscope, the position of the telescopic end in reference to the tube is easily determined by estimation to 0·0005 inch, and with care to 0·00025, the reading being to 0·001.

The tube is supported in a stout mahogany box at two points, on a roller at one, and suspended by a vertical arm and cross-piece at the other. The box is provided with brass brackets at each end, by means of which it rests upon the spherical heads. One bracket has a spherical cup, the other bracket a cylindrical groove.

By means of suitable screws and springs the plane ends of the steel tube are brought into firm contact with the spherical heads, so that the centres of the spheres lie in the axis of the tube. The temperature of the tube is indicated by two thermometers.

Most of the comparisons have been taken on two iron brackets firmly attached to the stone wall of the observatory, but I have constructed a wooden bench carrying two iron plates at each end, connected by two steel rods from end to end in such a manner as to withstand the springs of the steel tube or standard 10-feet measure. In this way I have got results about 0·0002 inch less than when the comparisons were made on the iron brackets.

Six sets of comparisons, consisting of five each set on the iron brackets, gave 10·00296 feet as the value of the measuring rod, with a mean error of each set of 0·000015 foot. Another six sets on different days gave 10·002951 feet as the value, with a mean error of each set of 0·000012 foot. With greater reading power I have no doubt that one set of comparisons would give the value of the rod to 0·0001 inch or 0·00001 foot.

The average difference of the two thermometers on the 10-feet standard in 125 comparisons was 0°·93 F., and the 10-feet measuring rod under similar circumstances 0°·69 F. The difference between the attached and detached thermometers adjoining one another on the measuring rod in 145 comparisons was 0°·16 F., showing a close approximation of the steel rod to the temperature of the air. Two persons can make five comparisons in $12\frac{1}{2}$ minutes.

Experiments for expansion gave a coefficient of 61·5 ten-millionths for 1° F. for both rods, with a probable error of 1·0 ten-millionth. One hundred feet have been set off with the measuring rod eight times with a mean error of 0·0005 foot, showing that the apparatus is capable of doing reliable work to 1 in 200,000. One hundred yards can be measured easily in one hour with one assistant.

The accompanying drawings will make the above description clear.

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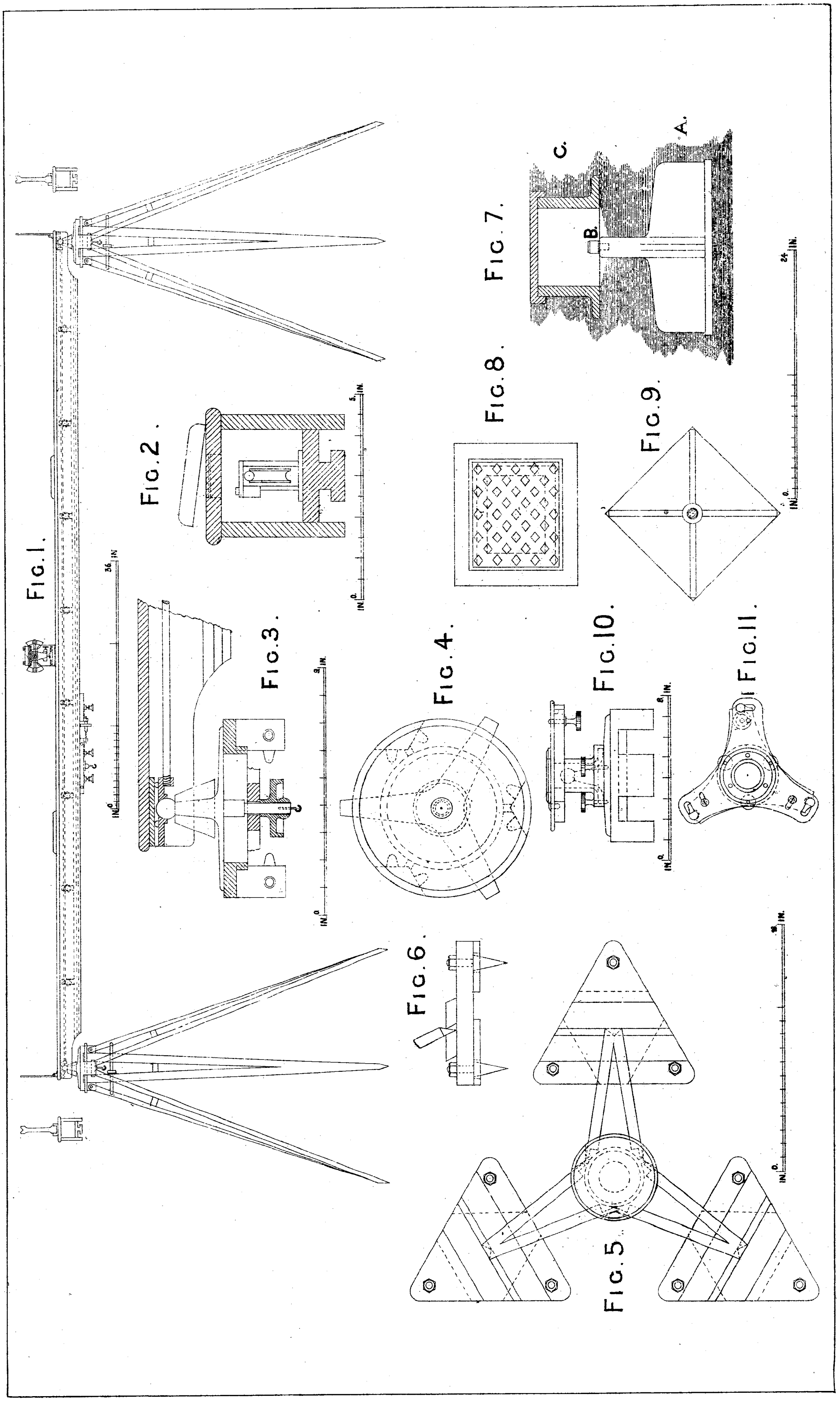

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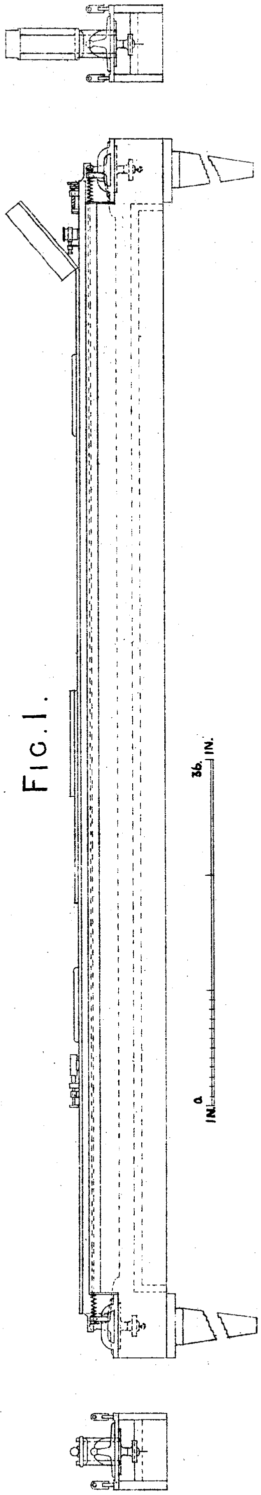


Fig. 1.

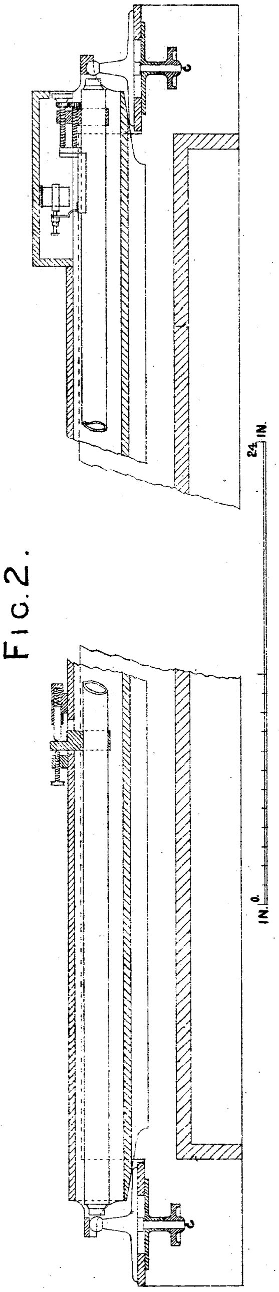


Fig. 2.

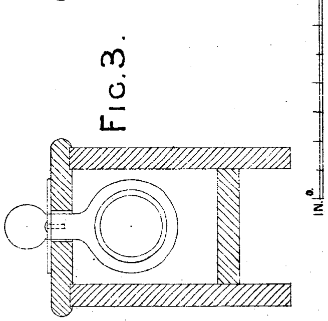


Fig. 3.

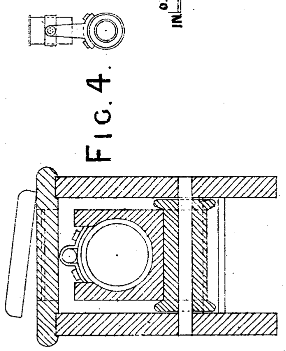
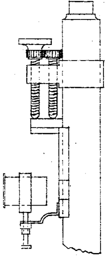


Fig. 4.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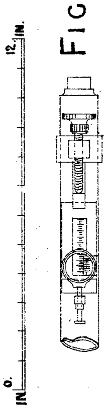

Fig. 6.

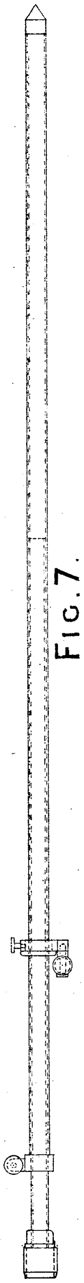
Fig. 7.

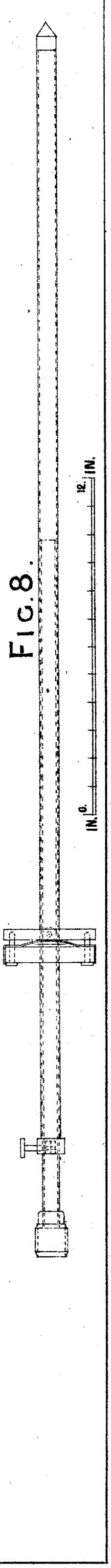

Fig. 8.

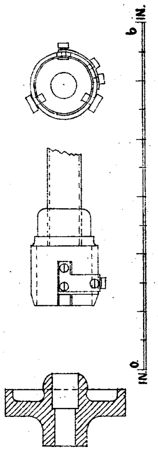

Fig. 9.

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Plate 1.

Fig. 1 is the measuring rod of square box section resting on two tripods.

Fig. 2 is a section of the rod. The steel rod is indicated in both drawings passing through the middle of the box on rollers. At each end of the rod are sights for lining. In the centre is the clinometer, and between these the two thermometers.

Underneath the rod is a sliding piece, with clamps and slow motion and hook for plumb bob for measuring part lengths, the rod being divided every six inches, an ivory scale divided on both edges giving intermediate lengths to the hundredth of an inch.

Fig. 3 shows the end of the rod and the top of the tripod in section, and fig. 4 the top of the tripod in plan.

Figs. 5 and 6 show a method of supporting the tripods so as to facilitate the levelling of the rings, by moving the feet along the grooves tangentially, and thus tilting the rings to any desired position.

Fig. 7 shows the terminal mark, consisting of an iron casting A, surmounted by a brass step with cap at B. C is the box frame and lid for making good the surface of the ground.

Fig. 8 is a plan of C.

Fig. 9 is a plan of A.

Figs. 10 and 11 show a pedestal suitable for supporting a theodolite centrally over the spherical head on one of the tripods.

Plate 2.

Fig. 1 shows the standard 10-feet rod resting upon two spherical heads upon the wooden comparing bench.

Fig. 2 shows the above in longitudinal section.

Figs. 3 and 4 are sections of the rod.

Figs. 5 and 6 show the telescopic end of the steel tube, with reading microscope and adjusting screws.

Figs. 7 and 8 show a telescopic tubular rod, which is more convenient than the plumb bob. The lower end is conical, and fits into the brass step on the terminal. The upper end is cylindrical, and embraces the spherical portion of the milled head as shown in section, fig. 9. The rod will then rotate on these two centres, and by means of the attached level the vertical position is easily found with considerable accuracy.